Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 10(X), 2022: http://dx.doi.org/

A review on characteristics of pervious concrete using recycled aggregate.

Una revisión de las características del hormigón permeable que utiliza áridos reciclados

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ABSTRACT

Pervious concrete is a mixture of cement, coarse aggregate mixed with water. The absence of fine aggregate helps increase the voids and water can pass through these gaps and reaches to ground level. The use of recycled coarse aggregates from construction and demolition is a sustainable solution with many environmental benefits and also reduces the number of virgin aggregates to be created, hence reducing the extraction of natural resources. This paper reviews the research developments of pervious concrete by replacing natural aggregates with different percentages of recycled coarse aggregate. The papers under consideration of review have conducted to identify various properties of pervious concrete such as mechanical and hydrological properties.

Keywords— pervious concrete, compressive strength, permeability

RESUMEN

El hormigón permeable es una mezcla de cemento, agregado grueso mezclado con agua. La ausencia de agregado fino ayuda a aumentar los vacíos y el agua puede pasar a través de estos espacios y llegar al nivel del suelo. El uso de áridos gruesos reciclados de construcción y demolición es una solución sostenible con muchos beneficios medioambientales y además reduce el número de áridos vírgenes a crear, reduciendo así la extracción de recursos naturales. Este artículo revisa los desarrollos de investigación del concreto permeable al reemplazar agregados naturales con diferentes porcentajes de agregado grueso reciclado. Los artículos bajo consideración de revisión se han realizado para identificar varias propiedades del hormigón permeable, como propiedades mecánicas e hidrológicas.

Palabras clave: hormigón permeable, resistencia a la compresión, permeabilidad.

INTRODUCTION

Sustainable development is now needed as our planet faces an uncertain future. Many areas are covered with impervious surfaces like parking lots, driveways, sideways and streets which do not allow the percolation of water through the ground. Storm water management has become a prime factor for cities and municipalities due to urban sprawl. The impervious nature of conventional pavement system has led to an increase in storm water runoff quantity that has stemmed in a large volume of first flush containing unacceptable level of pollutants and flooding. Pervious concrete is a special type of concrete characterized by a pore structure and high void content, which allows percolation of water through its structure. It is different from the conventional concrete because it contains a nominal or no amount of fine aggregate. It is also known as permeable concrete, porous concrete or no-fine concrete. It has been used in low traffic pavements such as parking lots and sidewalks.

Landfills are becoming increasingly difficult to find, are too remote from the demolition site, or are too costly to maintain. At the same time, sources of supply of suitable aggregate for making concrete are continuously being exhausted. The recycling of demolition waste materials into new buildings can provide a solution to these problems. Recycling is the act of processing the used material for use in creating new product. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions (Manjushree G. Shinde et al., 2013).

MATERIALS AND METHODS

Pervious concrete: Pervious concrete is a porous lightweight concrete made of aggregate, cement and water at a certain ratio. It is considered to be porous concrete because of its pore structure and excellent permeability. Its structure with interconnected voids allows both water and air to percolate through and reduces runoff (Alireza Joshaghani et al., 2014). The typical porosity of pervious concrete ranged from 15 to 30% (ACI Committee 522, 2006). As a storm water management tool, pervious concrete is used to construct low volume pavement infrastructure such as sidewalks, driveways, parking lots and residential roads. It is an accepted fact that pervious concrete is lower in strength compared with conventional concrete mixtures, hence the reason for its application in low-traffic roads, parking lots, driveways and sidewalks (Tennis et al., 2004). Pervious concrete is normally used without any reinforcement due to high risk of corrosion because of the open pores in its structure. Some applications of Pervious concrete include pervious pavement for

parking lots, rigid drainage layers under exterior areas, greenhouse floors to keep the floor free of standing water, structural wall applications where lightweight or better thermal insulation characteristics, or both are required, elements where better acoustic absorption characteristics are desired, base course for roads, surface course for parking lots, tennis courts, zoo areas, animal barns, swimming pool decks, beach structures, seawalls, embankments, etc (M. Sonebi et al., 2016). It can facilitate good resistance to skidding due to its characteristic rough surface texture, reduce flash flooding, minimize urban heating, allow tree roots to breathe and also reduce the need for runoff retainers reducing the property costs. It can also reduce the impact of tree development. Pervious concrete pavement allows the transfer of both water and air to root systems that allows trees to thrive even in highly developed areas. It can act as a filter, which can retain the pollutants in the first flush of rainfall, and prevents the streams, ponds, and rivers from entering. It allows water to pass through its structure due to an increased air voids network. Pervious concrete is a suitable material to be considered for increased usage in the development of sustainable pavement.

Mechanical properties of pervious concrete: The various properties of pervious concrete are primarily dependent on its porosity, which in turn depends on cementitious content, water-cement ratio, compaction level, aggregate gradation and quality (ACI Committee 522, 2006). High porosity and permeability properties are the main characteristics pertinent to pervious concrete as it has a very high void ratio in the range of about 15-35% (Alireza Joshaghani et al., 2014). At higher porosity ratios, the permeability coefficient is increased, but the compressive strength and flexural strength are decreased, thus it is necessary to optimize the porosity in order to gain the desired strength and permeability coefficient (Haitang Zhu et al., 2020). Experiments has shown that a water-cement ratio of 0.26 to 0.45 provides good aggregate coating and paste stability (ACI Committee 522, 2006). Based on the studies conducted, it is evident that the size of the aggregate had a critical effect on all strength properties. The 4.75-9.5 mm sized aggregate had the maximum compressive strength of 10.41 MPa corresponding to the lowest porosity and the 12.5-19 mm sized aggregate had the lowest compressive strength of 6.21 MPa. With the increase in the aggregate size, the strength of the pervious concrete decreases, the bulk density of aggregate is decreased and the connection between the aggregate decreases, therefore it leads to reduction of strength of the pervious concrete. Also, an increased aggregate amount in coarse aggregate resulted in a significant decrease in compressive strength due to the subsequent decrease in paste amount (Alireza Joshaghani et al., 2014).

The durability of pervious concrete refers to the service life under given environmental conditions (ACI Committee 522, 2006). Resistance of pervious concrete to

freezing-thawing cycles and abrasion are the challenging durability issues. The performance of pervious concrete under freezing-thawing conditions is affected by the number of cycles and their frequency. By altering the mix design of pervious concrete by introducing sand, latex and even air-entrainment, the resistance of pervious concrete to freezing-thawing cycles will improve due to preventing debonding between the aggregates and cement paste. Higher compaction energy will obviously make the matrix less porous, and thus improving its resistance to freezing-thawing cycles (M. Sonebi et al., 2016). In addition, proper maintenance of pervious concrete will likely reduce its failure due to frost action by allowing water to pass through it freely without being trapped inside the pore structure. This maintenance process can be done annually by either spraying or using vacuum to remove debris that can clog the pore structure of pervious concrete (M. Zaldo, 2006)

Properties of recycled aggregate: Due to modernization, demolished materials are dumped on land and not used for any purpose. Construction and pre-used specimen wastes can be used as recycled aggregate. Out of the total construction demolition waste, 40% is of concrete, 30% ceramics, 5% plastics, 10% wood, 5% metal, and 10% other mixtures. Recycled aggregates is produced from aged concrete that has been demolished and removed from foundations, pavements, bridges or buildings. It is crushed and processed into various size fractions and the reinforcing steel and other embedded items are removed, if any.

Sieve analysis is carried out as per IS 2386 for crushed recycled concrete aggregate and natural aggregates. It is found that recycled coarse aggregate are reduced to various sizes during the process of crushing and sieving, which gives the best particle size distribution. The specific gravity in saturated surface dry condition of recycled concrete aggregate was found from 2.35 to 2.58 which are less but satisfying the results. If specific gravity is less than 2.4, it may cause segregation, honeycombing and also yield of concrete may get reduced (Tushar R Sonawane and Sunil S. Pimplikar, 2013).

The recycled coarse aggregates from demolished concrete consist of crushed stone aggregate with old mortar adhering to it which results in the water absorption ranging from 1.5% to 7.0%, which is relatively higher than that of the natural aggregates (Tushar R Sonawane and Sunil S. Pimplikar, 2013). It is important that water absorption of recycled aggregate is determined carefully prior to their use in concrete as the strength of concrete decreases with increase in water absorption (Manjushree G. Shinde et al., 2013).

Effect of recycled aggregate in pervious concrete: Recycled aggregates are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris (Manjushree G. Shinde et al., 2013). The use of recycled aggregate in concrete can be useful for environmental protection. The compressive strength and split tensile strength of pervious concrete with recycled aggregate is found to

be less than pervious concrete made with normal aggregates (P.C Bala murugan et al., 2019 and Jian-Xin lu et al., 2019). This strength reduction can be due to poor aggregate-cement paste bonding in recycled coarse aggregate mixes. The presence of adhered mortar on recycled coarse aggregate will absorb the mixing water and it reduces the amount of cement paste. This eventually results in poor bonding between cement paste and coarse aggregate and compressive strength is reduced. The use of silica fume in the cement paste was found to be effective in compromising lower compressive strength (P.C Bala murugan et al., 2019).

Pervious concrete having single coarse-sized aggregates exhibited much higher permeable coefficient than pervious concrete prepared with having small-sized aggregates, but had lower compressive strength (Jian-Xin lu et al., 2019). The increase in water-cement ratio and replacement ratio also increased the void content and permeability coefficient of pervious concrete. The permeability of pervious concrete at water-cement ratio of 0.25 was found lower than that of pervious concrete at water-cement ratio of 0.3. The reason may be due to the specimen with lower water-cement ratio has thicker cement slurry thickness and higher pore fill rate, which all make pervious concrete difficult to form unobstructed vertical permeable approach and decrease the permeability performance (Weidong Zhang et al., 2019).

Pervious concrete mix with 20% recycled coarse aggregate replacement showed very close compressive strength to that natural aggregate mix, but for recycled coarse aggregate replacement greater than 20%, the compressive strengths of recycled coarse aggregate mixes reduced (Soon Poh Yap et al., 2018). The strength enhancement of recycled aggregate pervious concrete can be done using a cement paste distribution method. For this a silane polymer emulsion treatment method was adopted to improve the strength of pervious concrete while maintaining its permeability. The results showed that the strength of pervious concrete is increased due to the redistribution of cement paste (Tiejun Liu et al., 2019).

The compressive strength of pervious concrete increased with a reduction in the maximum aggregate size from 20 to 13 mm (Rasiah Sriravindrarajah et al., 2012). The effect of aggregate size was studied by considering aggregate sizes of 9.5 mm and 19 mm. Percentage increase in permeability for 9.5mm aggregate size is found to be 13.3% and 18.8% for 50% and 100% recycled aggregate replacement levels, respectively. The reduction in 28 days compressive strength using 9.5 mm aggregate size is 5% and 31% for 50% and 100% replacement levels, respectively. This negative effect could be because of higher voids ratio and bad bonding between recycled coarse aggregate and cement paste. Use of recycled coarse aggregate slightly decreases the fresh and hardened density of PC because of lower density and higher void ratio of recycled coarse aggregate (Ali A. Aliabdo et al., 2018).

The strength properties of pervious concrete block by using natural aggregates and

plastic coated aggregates were determined for a water-cement ratio of 0.4 and 0.35. The compressive strength of pervious concrete using natural aggregate is found to be 8.21 MPa and 11.18 MPa for a water-cement ratio of 0.4 and 0.35. And for pervious concrete using plastic coated aggregate, the compressive strength is found to be 9.80 MPa and 7.54 MPa for a water cement ratio of 0.4 and 0.35 respectively. The results showed that the compressive strength pervious concrete using plastic coated aggregates has slightly less strength compared to pervious concrete using natural aggregates (Rahul Jichkar et al., 2018).

The mechanical properties of pervious concrete by replacing natural aggregates with crushed sea shells were investigated and the compressive strength of shell pervious concrete varied from 15.2 to 18.6 MPa. The decrease in compressive strength compared to conventional pervious concrete is about 13.2% to 29.2% and decrease in tensile strength is about 11.8% to 18.8%. The decrease in mechanical strength may be attributed to the fragile nature of seashells and also the porosity of crushed seashell is more compared to natural aggregate. Shells concrete is found to have lower density because of its porous structure. The permeability of pervious concretes with or without crushed shells varies between 2.2 and 3.4 mm/s. The freeze and thaw durability of concrete with shells is found weaker than the control pervious concrete. The chemical characteristics of crushed shells have an influence remarkable on the freeze and thaw durability of seashells pervious concrete (Dang Hanh Nguyen et al., 2017).

RESULTS AND DISCUSSIONS

Pervious concrete using recycled coarse aggregates have less strength properties when compared to pervious concrete using natural aggregates. It is found that the aggregate size also had a significant effect on strength properties of pervious concrete (Rasiah Sriravindrarajah et al., 2012). Water absorption of the recycled aggregates is found 9-10% higher than the normal aggregates (P.C Bala murugan et al., 2019). Water permeability of pervious concrete tends to get increased as the percentage of recycled aggregate is increased (Jian-Xin lu et al., 2019).

Pervious concrete is one of the most environmentally friendly and cost-effective solution to support sustainable construction. It is designed to have enhanced number of interconnected voids that allow water to flow through the material. Because of its ability to reduce runoff, it is commonly used as pavement material. It has been found that replacement of natural aggregates with recycled aggregates have led to an increase in the coefficient of permeability. The use of recycled aggregate reduces the strength parameters, which may be due to the presence of adhered mortar on recycled coarse aggregate that will absorb mixing water and reduces the amount of cement paste. This leads to poor bonding between cement paste and coarse aggregates. Addition of supplementary cementitious

materials shows an increase in strength parameters of pervious concrete. Pervious concrete can be utilised effectively when it is designed, performed and maintained properly.

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Received: 30th January 2021; Accepted: 10th March 2021; First distribution: 01th April 2021